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## U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371ATTORNEY'S DOCKET NUMBER  
566.41191X00 filed February 15, 2002

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)

10/049672

INTERNATIONAL APPLICATION NO.  
PCT/JP00/05508INTERNATIONAL FILING DATE  
August 17, 2000PRIORITY DATE CLAIMED  
August 17, 1999TITLE OF INVENTION  
POLISHING MEDIUM FOR CHEMICAL-MECHANICAL POLISHING, AND METHOD OF POLISHING SUBSTRATE MEMBER

## APPLICANT(S) FOR DO/EO/US

KURATA, YASUSHI KAMIGATA, YASUO UCHIDA, TAKESHI TERASAKI, HIROKI IGARASHI, AKIO

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ is transmitted hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office(RO/US)
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

## Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☒ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 131cr 2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information: Figs. 1a-1h, Credit Card Payment Form, International Publication No. WO 01/13417-coversheet, International Search Report, International Preliminary Examination Report



566.41191X00

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Applicants: Yasushi KURATA, ET AL.

Serial No.: Not Assigned

Filed: February 15, 2002

For: POLISHING MEDIUM FOR CHEMICAL-MECHANICAL POLISHING,  
AND METHOD OF POLISHING**PRELIMINARY AMENDMENT**Assistant Commissioner of Patents  
Washington, DC 20231

February 15, 2001

Sir:

Please amend the above-identified application as follows:

**IN THE SPECIFICATION:****Please replace the paragraph beginning at page 10, line 6, with the following rewritten paragraph:**

Accordingly, in the present invention, a polishing medium may preferably be comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; a second polishing medium containing abrasive grains, and the abrasive grains having an average particle diameter of 50 nm or less and standard deviation of particle size distribution in a value of more than 5 nm.

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**Please replace the paragraph beginning at page 10, line 14, with the following rewritten paragraph:**

The polishing medium of the present invention have a pH of 3 or less and contain the oxidizing agent in a concentration of from 0.01 to 3% by weight. The polishing medium having a low pH and containing the oxidizing agent in a low concentration can keep the dishing, thinning and polish scratches from occurring in copper or copper alloy wirings, and can materialize high-rate polishing of barrier layers in a low abrasive-grain concentration.

**Please replace the paragraph beginning at page 17, line 3, with the following rewritten paragraph:**

A second polishing medium for CMP of the present invention is the polishing medium comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; the polishing medium further containing abrasive grains, and the abrasive grains having an average particle diameter of 50 nm or less and a standard deviation of particle size distribution, of more than 5 nm. This second polishing medium, too, may preferably be so regulated that it has a pH of 3 or less and contains the oxidizing agent for conductors in a concentration of from 0.01 to 3% by weight. If necessary, a water-soluble polymer maybe added. Abrasive grains having an average particle diameter of 30 nm or less and having a standard deviation of particle size distribution of more than 10 nm are particularly preferred in the present invention. If they have a large average particle diameter of more than 50 nm, a low polishing rate may result on the barrier layer, and a high polishing rate on the silicon dioxide film. Also, even when they have an average particle diameter of 50 nm or less, a high polishing rate tends to result on the silicon dioxide flint if their standard deviation of particle size distribution is

50 nm or less.

**Please replace the paragraph beginning at page 21 , line 19, with the following rewritten paragraph:**

As described above, where in the present invention the polishing medium for CMP has a low pH of less than 3 and a low oxidizing-agent concentration (the oxidizing agent is in a concentration of about 0.15% by weight), the polishing rate of the tantalum, tantalum alloy or tantalum nitride or other tantalum compound used as the barrier layer can reach a maximum. Where its pH is less than 3, the etching rate of the copper or copper alloy comes higher, but, because of the sufficiently low concentration of the oxidizing agent, can be controlled by the protective-film-forming agent. Also, where the abrasive grains of colloidal silica or colloidal alumina having an average particle diameter of 50 nm or less is used, which lowers the polishing rate of silicon dioxide, the polishing-rate ratio (Ta/Cu or TaN/Cu) between tantalum or tantalumnitride and copper (inclusive of copper alloys) can be made more than 1 and also the polishing-rate ratio (Ta/SiO<sub>2</sub> or TaN/SiO<sub>2</sub>) between tantalum or tantalumnitride and silicon dioxide can be made more than 10.

**Please replace the paragraph beginning at page 27 , line 4, with the following rewritten paragraph:**

As shown in Table 1, to a mixture of 0.4% by weight of an acid, abrasive grains (but not added in Example 1; 1 part by weight in Examples 2 to 7 and Comparative Examples 1 and 2; and 1% by weight in Examples 8 to 11, 0.05 part by weight of a water-soluble polymer (but only in Examples 4, 6 and 7) and 0.2% by weight of a protective-film-forming agent (BTA), water(98/85 parts by weight in Examples 1 to 7 and Comparative Examples

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1 and 2, and 97.9% by weight in Examples 8 to 11 was added to effect dissolution, followed by addition of hydrogen peroxide water (a guaranteed reagent, an aqueous 30% solution) as an oxidizing agent for conductors to obtain polishing mediums for CMP. Here, as the abrasive grains, colloidal silica with an average particle diameter of 20 to 60 nm was added which was prepared by hydrolysis in an ammonia solution of tetraethoxysilane. Also, the malic acid and glycolic acid used each had a pKa of 3.2.

**Please replace the paragraph beginning at page 29, line 14, with the following rewritten paragraph:**

Foamed polyurethane resin with closed cells.

Polishing pressure: 25 kPa (250 gf/cm<sup>2</sup>).

Relative speed of substrate member to polishing platen:

18 m/minute.

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Please replace the paragraph beginning at page 32 , Table 2, with the following rewritten Table 2:

Table 2					
Example	CMP polishing rate (nm/minute)				Copper etching rate (nm/minute)
	Copper	Tantalum	Tantalum nitride	silicon dioxide	
1		4.0	5.0	0	0.5
2		36.2	54.7	0.8	0.8
3		24.9	44.9	1.3	3.2
4		34.9	24.9	1.2	0.3
5		33.0	615	1.3	0.7
6		20.0	25.0	1.3	0.6
7		1.1	5.5	1.7	0.4
Comparative Example					
1		10.5	17.3	1.2	6.7
2		2.0	3.0	0.7	0.1
10	11.4	36.2	54.7	0.8	
11	3.2	28.8	43.2	0.8	
12	13.0	22.0	43.4	6.7	
13	23.4	30.4	57.7	9.5	

Please replace the paragraph beginning at page 33, Table 3, with the following rewritten Table 3:

Table 3													
	Example												
	12												
Dising level (nm)	40	55	70	45	55	45	65	100	55	40	40	60	55
Thinning level (nm)	20	30	35	30	35	30	70	55	70	20	20	60	100

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**Please replace the paragraph beginning at page 33 , line 3, with the following rewritten paragraph:**

In Example 1 to 11, good dishing- and thinning-preventive performance has been achieved. In particular, in Examples 1 to 6, in which the oxidizing agent is in a concentration of from 0.01 to 3% by weight and the pH is 3 or less, the polishing rates of tantalum and tantalum nitride are so high and the dishing level and thinning level are so small as to be especially preferable. Also, in Examples 8 and 9, the polishing rate of tantalum nitride film is high and the polishing rate of silicon dioxide film is relatively low, and hence good dishing- and thinning—preventive performance is achieved.

**Please replace the paragraph beginning at page 34 , line 10, with the following rewritten paragraph:**

Example 2, in which the oxidizing agent is in a concentration of 3% by weight or less and the pH is 3 or less, is also preferable because the etching rate of copper is lower than that in Comparative Example 1, in which the oxidizing agent is in a concentration of more than 3% by weight, and also the polishing rate of tantalum or tantalum nitride is higher and the level of dishing and thinning is smaller than those Comparative Example 2, in which the pH is more than 3.

**Please replace the paragraph beginning at page 34 , line 16, with the following rewritten paragraph:**

In Examples 8 to 9, the polishing rate of the barrier layer film (in particular, the tantalum film) is higher and the polishing rate of the silicon dioxide film is lower than



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those in Example 10, in which the abrasive grains have a large particle diameter. Thus, these Examples are superior in view of the dishing- and thinning-preventive performance. Also, in Examples 8 to 9, the polishing rate of the barrier layer film (in particular, the tantalum film) is at the same rank as, but the polishing rate of the silicon dioxide film is lower than, those, in which the standard deviation of particle size distribution is smaller.

**IN THE CLAIMS:**

Please cancel claims 1-22 and insert new claims 23-40.

23. A polishing medium for chemical-mechanical polishing, comprising:

an oxidizing agent for a conductor; a protective-film—forming agent for protecting a metal surface; an acid; and water, not comprising abrasive gains, wherein:

said polishing medium has a pH of 3 or less, and said oxidizing agent is in a concentration of from 0.01% by weight to 3% by weight.

24. The polishing medium for chemical-mechanical polishing, comprising:

an oxidizing agent for a conductor; a protective-film-forming agent for protecting a metal surface; an acid; water; and abrasive grains;

said abrasive grains are colloidal silica or colloidal alumina,

said abrasive grains have a pH of 3 or less; and

said an oxidizing agent is in a concentration of from 0.01% by weight to 3% by weight.

25. The polishing medium for chemical-mechanical polishing according to claim 24, wherein:

said abrasive grains have a average particle diameter of 50 nm or less, and said abrasive grains have standard deviation of particle size distribution in a value of more than 5 nm..

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26. The polishing medium for chemical-mechanical polishing according to claim 24, wherein said abrasive grains are mixed in an amount of from 0.1% by weight to 5% by weight.

27. The polishing medium for chemical-mechanical polishing according to claim 24, which further comprises a water-soluble polymer.

28. The polishing medium for chemical-mechanical polishing according to claim 27, wherein said water-soluble polymer is at least one selected from the group consisting of polyacrylic acid, a polyacrylic acid salt, polymethacrylic acid, a polymethacrylic acid salt, polyamic acid, a polyamic acid salt, polyacrylamide, polyvinyl alcohol and polyvinylpyrrolidone.

29. The polishing medium for chemical-mechanical polishing according to claim 27, wherein said oxidizing agent is in a concentration of from 0.01% by weight to 1.5% by weight.

30. The polishing medium for chemical-mechanical polishing according to claim 24, wherein said acid is an organic acid.

31. The polishing medium for chemical-mechanical polishing according to claim 30, wherein said acid is at least one selected from malonic acid, malic acid,

tartaric acid, glycolic acid and citric acid.

32. The polishing medium for chemical-mechanical polishing according to claim 24, wherein said protective-film-forming agent is at least one selected from benzotriazole and a derivative thereof.

33. The polishing medium for chemical-mechanical polishing according to claim 24, wherein said oxidizing peroxide, nitric acid, potassium periodate, hypochlorous acid and ozone water.

34. The polishing medium for chemical-mechanical polishing according to claim 24, wherein said conductor contains at least one of copper, a copper alloy, a copper oxide and a copper alloy oxide.

35. The polishing medium for chemical-mechanical polishing according to claim 24, wherein said conductor is a barrier layer for preventing copper atoms from diffusing.

36. The polishing medium for chemical-mechanical polishing according to claim 35, wherein said barrier layer contains tantalum, a tantalum alloy or a tantalum compound.

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37. As polishing condition, polishing pressure is 25 kPa and relative speed of substrate member to polishing platen is 18 m/minute, a polishing medium for chemical-mechanical polishing having:

a polishing-rate ratio (Ta/Cu) between tantalum and copper or a copper alloy of more than 1;

a polishing-rate ratio (TaN/Cu) between tantalum nitride and copper or a copper alloy of more than 1;

a polishing-rate ratio (Ta/SiO<sub>2</sub>) between tantalum and silicon dioxide of more than 10; and

a polishing-rate ratio (TaN/SiO<sub>2</sub>) between tantalum nitride and silicon dioxide film of more than 10.

38. As polishing condition, polishing pressure is 25 kPa and relative speed of substrate member to polishing platen is 18 m/minute, the polishing medium for chemical-mechanical polishing according to claim 23, which has:

a polishing-rate ratio (Ta/Cu) between tantalum and copper or a copper alloy of more than 1;

a polishing-rate ratio (TaN/Cu) between tantalum nitride and copper or a copper alloy of more than 1;

a polishing-rate ratio (Ta/SiO<sub>2</sub>) between tantalum and silicon dioxide of more than 10; and

a polishing-rate ratio (TaN/SiO<sub>2</sub>) between tantalum nitride and silicon dioxide film

of more than 10.

39. A method of polishing a substrate member comprising a step of polishing a barrier layer containing tantalum, a tantalum alloy or a tantalum compound, by the use of the polishing medium for chemical-mechanical polishing according to claim 38.

40. A method of polishing a substrate member comprising a step of polishing a surface including a wiring layer and a barrier layer, by the use of the polishing medium for chemical-mechanical polishing according to claim 38.

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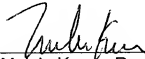
**REMARKS**

By the above preliminary amendment the specification and claims have been amended to incorporate Article 34 Amendments as shown on the attachments and to present additional amendments so that claims 1-22 have been canceled and new claims 23-40 presented.

To the extent necessary, applicants petition for an extension of time under 37 CFR §1.136. Please charge any shortage in the fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 01-2135 (566.41191X00) and please credit any excess fees to such deposit account.

Respectfully submitted,

ANTONELLI, TERRY, STOUT & KRAUS, LLP



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Melvin Kraus, Registration No. 26,422

MK:dmw  
(703) 312-6600

**VERSION WITH MARKINGS TO SHOW CHANGES MADE****IN THE SPECIFICATION:**

**Please replace the paragraph beginning at page 10 , line 6 , with the following rewritten paragraph:**

Accordingly, [the present invention also provides a polishing medium comprising an oxidizing agent for conductors,] in the present invention, a polishing medium may preferably be comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; [the polishing medium] a second polishing medium containing abrasive grains, and the abrasive grains having an average particle diameter of 50 nm or less and standard deviation of particle size distribution in a value of more than 5 nm.

**Please replace the paragraph beginning at page 10, line 14, with the following rewritten paragraph:**

[This polishing medium] The polishing medium of the present invention [may preferably] have a pH of 3 or less and contain the oxidizing agent in a concentration of from 0.01 to 3% by weight. The polishing medium having a low pH and containing the oxidizing agent in a low concentration can keep the dishing, thinning and polish scratches from occurring in copper or copper alloy wirings, and can materialize high-rate polishing of barrier layers in a low abrasive-grain concentration.

**Please replace the paragraph beginning at page 17, line 3, with the following rewritten paragraph:**



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A second polishing medium for CMP of the present invention is the polishing medium comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; the polishing medium further containing abrasive grains, and the abrasive grains having an average particle diameter of 50 nm or less and a standard deviation of particle size distribution, of more than 5 nm. This second polishing medium, too, may preferably be so regulated that it has a pH of 3 or less and contains the oxidizing agent for conductors in a concentration of from 0.01 to 3% by weight. If necessary, a water-soluble polymer maybe added. Abrasive grains having an average particle diameter of 30 nm or less and having a standard deviation of particle size distribution of more than 10 nm are particularly preferred in the present invention. If they have a large average particle diameter of more than 50 nm, a low polishing rate may result on the barrier layer, and a high polishing rate on the silicon dioxide film. Also, even when they have an average particle diameter of 50 nm or less, a high polishing rate tends to result on the silicon dioxide flint if their standard deviation of particle size distribution is [less than 5 nm] 50 nm or less.

**Please replace the paragraph beginning at page 21 , line 19, with the following rewritten paragraph:**

As described above, where in the present invention the polishing medium for CMP has a low pH of less than 3 and a low oxidizing-agent concentration (the oxidizing agent is in a concentration of about 0.15% by weight), the polishing rate of the tantalum, tantalum alloy or tantalum nitride or other tantalum compound used as the barrier layer can reach a maximum. Where its pH is less than 3, the etching rate of the copper or copper alloy

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comes higher, but, because of the sufficiently low concentration of the oxidizing agent, can be controlled by the protective-film-forming agent. Also, where the abrasive grains of colloidal silica or colloidal alumina having an average particle diameter of [50 nm] 50 nm or less is used, which lowers the polishing rate of silicon dioxide, the polishing—rate ratio (Ta/Cu or TaN/Cu) between tantalum or tantalumnitride and copper (inclusive of copper alloys) can be made more than 1 and also the polishing-rate ratio (Ta/SiO<sub>2</sub> or TaN/SiO<sub>2</sub>) between tantalum or tantalumnitride and silicon dioxide can be made more than 10.

**Please replace the paragraph beginning at page 27 , line 4, with the following rewritten paragraph:**

As shown in Table 1, to a mixture of 0.4% by weight of an acid, abrasive grains (but not added in Example 1; [1 part by weight in Examples 2 to 9; and 1% by weight in Examples 10 to 13]) 1 part by weight in Examples 2 to 7 and Comparative Examples 1 and 2; and 1% by weight in Examples 8 to 11, 0.05 part by weight of a water-soluble polymer (but only in Examples 4, 6 and 7) and 0.2% by weight of a protective-film-forming agent (BTA), water [(98.85 parts by weight in Examples 1 to 9, and 97.9% by weight in Examples 10 to 13)] (98/85 parts by weight in Examples 1 to 7 and Comparative Examples 1 and 2, and 97.9% by weight in Examples 8 to 11 was added to effect dissolution, followed by addition of hydrogen peroxide water (a guaranteed reagent, an aqueous 30% solution) as an oxidizing agent for conductors to obtain polishing mediums for CMP. Here, as the abrasive grains, colloidal silica with an average particle diameter of 20 to 60 nm was added which was prepared by hydrolysis in an ammonia solution of tetraethoxysilane. Also, the malic acid and glycolic acid used each had a pKa of 3.2.

**Please replace the paragraph beginning at page 29, line 14, with the following rewritten paragraph:**

Foamed polyurethane resin with closed cells.

Polishing pressure: [250 gf/cm<sup>2</sup>] 25 kPa (250 gf/cm<sup>2</sup>).

Relative speed of substrate member to polishing platen:

18 m/minute.

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Please replace the paragraph beginning at page 32 , Table 2, with the following rewritten Table 2:

Table 2					
Example	CMP polishing rate (nm/minute)				Copper etching rate (nm/minute)
	Copper	Tantalum	Tantalum nitride	silicon dioxide	
1		4.0	5.0	0	0.5
2		36.2	54.7	0.8	0.8
3		24.9	44.9	1.3	3.2
4		34.9	24.9	1.2	0.3
5		33.0	615	1.3	0.7
6		20.0	25.0	1.3	0.6
7		1.1	5.5	1.7	0.4
Comparative Example					
1		10.5	17.3	1.2	6.7
2		2.0	3.0	0.7	0.1
10	11.4	36.2	54.7	0.8	
11	3.2	28.8	43.2	0.8	
12	13.0	22.0	43.4	6.7	
13	23.4	30.4	57.7	9.5	

Please replace the paragraph beginning at page 33, Table 3, with the following rewritten Table 3:

Table 3													
	Example												
	12												
Dising level (nm)	40	55	70	45	55	45	65	100	55	40	40	60	55
Thinning level (nm)	20	30	35	30	35	30	70	55	70	20	20	60	100

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**Please replace the paragraph beginning at page 33 , line 3, with the following rewritten paragraph:**

[In Examples 1 to 13] In Example 1 to 11, good dishing- and thinning-preventive performance has been achieved. In particular, in Examples 1 to 6, in which the oxidizing agent is in a concentration of from 0.01 to 3% by weight and the pH is 3 or less, the polishing rates of tantalum and tantalum nitride are so high and the dishing level and thinning level are so small as to be especially preferable. Also, [in Examples 10 and 11] in Examples 8 and 9, the polishing rate of tantalum nitride film is high and the polishing rate of silicon dioxide film is relatively low, and hence good dishing- and thinning—preventive performance is achieved.

**Please replace the paragraph beginning at page 34 , line 10, with the following rewritten paragraph:**

Example 2, in which the oxidizing agent is in a concentration of 3% by weight or less and the pH is 3 or less, is also preferable because the etching rate of copper is lower than that in [Example 8] in Comparative Example 1, in which the oxidizing agent is in a concentration of more than 3% by weight, and also the polishing rate of tantalum or tantalum nitride is higher and the level of dishing and thinning is smaller than those [in Example 9] Comparative Example 2, in which the pH is more than 3.

**Please replace the paragraph beginning at page 34 , line 16, with the following rewritten paragraph:**

[In Examples 10 and 11] In Examples 8 to 9, the polishing rate of the barrier layer

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film (in particular, the tantalum film) is higher and the polishing rate of the silicon dioxide film is lower than those [in Example 12] in Example 10, in which the abrasive grains have a large particle diameter. Thus, these Examples are superior in view of the dishing- and thinning-preventive performance. Also, [in Examples 10 and 11] in Examples 8 to 9, the polishing rate of the barrier layer film (in particular, the tantalum film) is at the same rank as, but the polishing rate of the silicon dioxide film is lower than, those [in Example 13] in Example 11, in which the standard deviation of particle size distribution is smaller.

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## SPECIFICATION

POLISHING MEDIUM FOR CHEMICAL-MECHANICAL POLISHING,AND5 METHOD OF POLISHING SUBSTRATE MEMBER

## TECHNICAL FIELD

This invention relates to a polishing medium for chemical-mechanical polishing, especially suited for  
10 polishing in the step of forming wirings of semiconductor devices, and a method of polishing a substrate member by the use of the same.

## BACKGROUND ART

15 In recent years, as semiconductor integrated circuits (hereinafter "LSI") are made high-integration and high-performance, new techniques for fine processing have been developed. Chemical-mechanical polishing (hereinafter "CMP") is also one of them, which is a  
20 technique often used in LSI fabrication steps, in particular, in making interlaminar insulating films flat in the step of forming multilayer wirings, in forming metallic plugs and in forming buried wirings. This technique is disclosed in, e.g., U.S. Patent No. 4,944,836.

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Recently, in order to make LSIs high-performance, it is also attempted to utilize copper or copper alloys as wiring materials. It, however, is difficult for the copper or copper alloys to be finely processed by dry etching often used in forming conventional aluminum alloy wirings. Accordingly, what is called the damascene method is chiefly employed, in which a copper or copper alloy thin film is deposited on an insulating film with grooves formed previously and is buried therein, and the copper or copper alloy at the part except the grooves is removed by CMP to form buried wirings. This technique is disclosed in, e.g., Japanese Patent Application Laid-open No. 2-278822.

In a common method for the CMP of metals such as copper and copper alloys, a polishing pad is fastened onto a circular polishing platen, and the surface of the polishing pad is soaked with a polishing medium, where a substrate with a metal film formed thereon is pressed against the pad on the former's metal film side and a stated pressure is applied thereto on the back thereof, in the state of which the polishing platen is turned, to remove the metal film at the part of its hills by mechanical friction acting between the polishing medium and the hills of the metal film.



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The polishing medium used in such CMP is commonly comprised of an oxidizing agent and abrasive grains, to which a metal-oxide-dissolving agent and a protective-film-forming agent are optionally added.

- 5 The basic mechanism of CMP making use of this polishing medium for CMP is considered to be that the metal film surface is oxidized with the oxidizing agent and the resultant oxide layer is scraped with the abrasive grains.

The oxide layer at the dales of the metal surface does  
10 not come into contact with the polishing pad so much and the effect of scraping attributable to the abrasive grains does not extend thereto. Hence, with progress of the CMP, the metal film becomes removed at its hills and the substrate surface become flat. Details on this  
15 matter are disclosed in Journal of Electrochemical Society, Vol. 138, No. 11 (published 1991), pages 3460-3464.

In order to make higher the rate of polishing by CMP, it is considered effective to add the metal-oxide-dissolving agent. It can be explained that  
20 this is because the effect of scraping attributable to the abrasive grains comes higher where grains of metal oxide scraped off by the abrasive grains are made to dissolve (hereinafter "etched") in the polishing medium. However, the addition of the metal-oxide-dissolving

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agent makes the oxide layer become etched (dissolve) also at the dales of the metal film surface, and the metal film surface becomes uncovered, so that the metal film surface is further oxidized by the oxidizing agent.

5 With repetition of this, the etching may proceed at the dales of the metal film surface. This may cause a phenomenon that the surface of the metal wiring having been buried after the polishing becomes hollow at the middle thereof like a dish (hereinafter "dishing"),  
10 resulting in a damage of the effect of flattening.

In order to prevent this phenomenon, the protective-film-forming agent is further added to the metal-polishing medium for CMP. The protective-film-forming agent forms a protective film  
15 on the oxide layer at the metal film surface to prevent the oxide layer from dissolving in the polishing medium.

It is desirable for this protective film to be readily capable of being scraped off by the abrasive grains and also not to lower the rate of polishing by CMP.

20 In order to keep the copper or copper alloy from causing the dishing or from corroding during the polishing, to form highly reliable LSI wirings, a polishing medium for CMP is proposed in which amino acetic acid (glycine) or amidosulfuric acid is used as the

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metal-oxide-dissolving agent and benzotriazole (hereinafter "BTA") is further used as the protective-film-forming agent. This technique is disclosed in, e.g., Japanese Patent Application Laid-open  
5 No. 8-83780.

In the buried-metal formation as in the formation of damascene wirings of copper or copper alloy or the formation of plug wirings of tungsten, a phenomenon called "thinning" in which the thickness of wiring becomes small  
10 together with an interlaminar insulating film may occur when an interlaminar insulating film silicon dioxide film formed except the buried part is polished at a rate close to the rate of polishing the metal film. As the result, it may cause an increase in wiring resistance  
15 or a non-uniformity in resistance ascribable to pattern density. Hence, the polishing medium for CMP is required to have a property that the polishing rate of the silicon dioxide film is sufficiently smaller than that of the metal film to be polished. Accordingly, a method is  
20 proposed in which the pH of the polishing medium is set higher than pKa of -0.5 so that the polishing rate of silicon dioxide can be controlled by negative ions produced as a result of dissociation of acid. This technique is disclosed in, e.g., Japanese Patent No. 2819196.

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Meanwhile, at the underlying layer of the copper or copper alloy of the wiring, a layer of tantalum, tantalum alloy, tantalum nitride or other tantalum compound is formed as a barrier layer in order to prevent the copper from diffusing into the interlaminar insulating film. Accordingly, the barrier layer must be removed by CMP, except the wiring part where the copper or copper alloy has been buried. However, the conductor constituting such a barrier layer has a higher hardness than the copper or copper alloy, and hence in many cases any sufficient polishing rate can not be achieved when it is used in combination with the polishing medium for the copper or copper alloy. Accordingly, studies are made on a two-step polishing method having a first step of polishing the copper or copper alloy and a second step of polishing the barrier layer conductor.

In the second-step CMP of the barrier layer, the dishing at the wiring part of buried copper or copper alloy must be prevented, it has been considered reverse-effective to make the polishing medium have a small pH value in order to control the polishing rate and etching rate of the copper or copper alloy.

The tantalum, tantalum alloy and tantalum compound (such as tantalum nitride) used in the barrier layer

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are chemically so stable that they can be etched with difficulty, and has so high a hardness that they can not so readily mechanically be polished as the copper or copper alloy. Hence, making the abrasive grains have  
5 a higher hardness may cause polish scratches in the copper or copper alloy to bring about poor electrical characteristics in some cases. Also, making abrasive-grain concentration higher may bring about a higher polishing rate of the silicon dioxide film to  
10 cause the problem that the thinning occurs.

## DISCLOSURE OF THE INVENTION

An object of the present invention is to provide a polishing medium for CMP which can keep the dishing,  
15 thinning and polish scratches from occurring in copper or copper alloy wirings, can materialize high-rate polishing of barrier layers in a low abrasive-grain concentration and can promise formation of highly reliable buried metal film patterns, and a substrate member  
20 polishing method making use of the same.

The present inventors made extensive studies in order to achieve this object. As the result, they have discovered that the polishing of the tantalum, tantalum alloy and tantalum compound, which are conductors used

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as the barrier layers, proceeds with ease when the polishing medium has a low pH and also the oxidizing agent is in a low concentration. Thus, they have accomplished the present invention. The present  
5 invention provides a first polishing medium for chemical-mechanical polishing, comprising an oxidizing agent for these conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; the polishing medium having a pH of 3 or less, and the  
10 oxidizing agent being in a concentration of from 0.01 to 3% by weight. This first polishing medium may further contain abrasive grains.

There have been the problems that making the abrasive grains have a higher hardness when the barrier layer  
15 is polished may cause polish scratches in the copper alloy to bring about poor electrical characteristics, and making the abrasive-grain concentration higher may bring about a higher polishing rate of the silicon dioxide film to cause the problem that the thinning may occur.

20 The present inventors have discovered that the polishing of the tantalum, tantalum alloy, tantalum nitride and other tantalum compounds which are used as the barrier layers proceeds with ease in a low pH range and in an oxidizing agent low-concentration range.

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Moreover, it has been found that, when such a polishing medium for CMP is used, the oxidizing agent is in a sufficiently low-concentration range, and hence the dishing of wirings does not come into question, which  
5 may occur with an increase in the etching rate of the copper or copper alloy and which may commonly come into question in a low-pH range.

The present inventors have also discovered that, in the polishing of the tantalum, tantalum alloy or  
10 tantalum compound used as the barrier layer conductor, any too large particle diameter of abrasive grains may bring about a decrease in polishing rate of the barrier layer and an increase in polishing rate of the silicon dioxide, and also that, even when the abrasive grains  
15 have a small particle diameter, any too small standard deviation of particle size distribution may bring about an increase in polishing rate of the silicon dioxide.

This phenomenon is remarkable when the tantalum, tantalum alloy or tantalum compound is polished with a polishing  
20 medium having a low pH and also containing the oxidizing agent in a low concentration.

It has been found that, when such a polishing medium is used, since the oxidizing agent is in a sufficiently low-concentration range, the dishing of wirings does

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not come into question, which may occur with an increase in the etching rate of the copper or copper alloy and which may commonly come into question in a low-pH range, and also any erosion may less occur because of a low  
5 abrasive-grain concentration.

Accordingly, the present invention also provides a polishing medium comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; the  
10 polishing medium containing abrasive grains, and the abrasive grains having an average particle diameter of 50 nm or less and standard deviation of particle size distribution in a value of more than 5 nm.

This polishing medium of the present invention may  
15 preferably have a pH of 3 or less and contain the oxidizing agent in a concentration of from 0.01 to 3% by weight.

The polishing medium having a low pH and containing the oxidizing agent in a low concentration can keep the dishing, thinning and polish scratches from occurring  
20 in copper or copper alloy wirings, and can materialize high-rate polishing of barrier layers in a low abrasive-grain concentration.

The polishing medium for CMP of the present invention may further contain a water-soluble polymer. In such



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a case, the oxidizing agent may preferably be in a concentration of from 0.01 to 1.5% by weight. The water-soluble polymer may preferably be at least one selected from the group consisting of polyacrylic acid  
5 or a salt thereof, polymethacrylic acid or a salt thereof, polyamic acid or a salt thereof, polyacrylamide, polyvinyl alcohol and polyvinylpyrrolidone.

The acid may preferably be an organic acid, and may more preferably be at least one selected from malonic  
10 acid, malic acid, tartaric acid, glycolic acid and citric acid.

The oxidizing agent for conductors may preferably be at least one selected from hydrogen peroxide, nitric acid, potassium periodate, hypochlorous acid and ozone  
15 water.

The protective-film-forming agent may preferably be at least one selected from benzotriazole (BTA) and a derivative thereof (hereinafter "BTAs").

The abrasive grains may preferably be at least one  
20 selected from silica, alumina, ceria, titania, zirconia, germania and silicon carbide. Colloidal silica or colloidal alumina having an average particle diameter of 50 nm or less is preferable for the present invention.

The abrasive grains may particularly preferably have

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an average particle diameter of 30 nm or less, and a standard deviation of particle size distribution of 10 nm or more. The abrasive grains may preferably be in a concentration of from 0.05 to 10% by weight, more preferably from 0.1 to 5% by weight, and particularly preferably from 0.2 to 3% by weight. The colloidal silica may preferably be a product obtained by hydrolysis of a silicon alkoxide. A product obtained using sodium silicate as a materials may also be used.

10       The polishing medium for CMP of the present invention may preferably have a polishing-rate ratio (Ta/Cu or TaN/Cu) between tantalum or tantalum nitride and copper (inclusive of copper alloys) of more than 1, and a polishing-rate ratio (Ta/SiO<sub>2</sub> or TaN/SiO<sub>2</sub>) between  
15   tantalum or tantalum nitride and silicon dioxide film of more than 10.

      The conductor (inclusive of semiconductors) suited for the polishing making use of the polishing medium for CMP of the present invention may include copper,  
20   copper alloys and copper oxides, and tantalum, tantalum alloys and tantalum compounds (such as tantalum nitride) which constitute barrier layers for the former (layers for preventing copper atoms from diffusing). Accordingly, the present invention provides a polishing method of

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polishing a barrier layer containing tantalum, a tantalum alloy or a tantalum compound (such as tantalum nitride), by the use of the polishing medium for CMP of the present invention, and also provides a polishing method of

5 polishing a surface including a wiring layer (copper, a copper alloy and/or an oxide thereof) and a barrier layer therefor (a layer for preventing copper atoms from diffusing), by the use of the polishing medium for CMP of the present invention.

10

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an illustration showing the steps of polishing a substrate member in Examples.

15

## BEST MODES FOR PRACTICING THE INVENTION

The polishing medium of the present invention is suited when a substrate member comprising a substrate which has on its surface a silicon dioxide with a dale

20 and on which a barrier layer and a metal film containing copper or copper alloy have been formed to fill the dale therewith is used as a polishing object. Such a substrate member is obtained by, e.g., as shown in Fig. 1, forming on the surface of a silicon wafer [Fig. 1 (a)] a silicon

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dioxide film 11 [Fig. 1 (b)], forming on the surface thereof a resist layer 12 having a stated pattern [Fig. 1 (c)], forming a dale 13 in the silicon dioxide film 11 by dry etching and then removing the resist layer 12 [Fig. 1 (d)], depositing a barrier metal such as tantalum by vacuum deposition, CVD or the like to form a barrier layer 14 [Fig. 1 (e)], and depositing a metal such as copper on the surface thereof by vacuum deposition, plating or CVD to provide a wiring layer 15 [Fig. 1 (f)].

10        This substrate member is subjected to CMP by the use of a polishing medium for copper and copper alloys which has a sufficiently large polishing-rate ratio between the wiring layer (copper and/or copper alloy) and the barrier layer, so that the barrier layer 14 at the hill (the part provided with the silicon dioxide 11) of the substrate member comes uncovered to the surface, thus the desired conductor pattern is obtained in which the wiring layer (copper or copper alloy film) 15 has been left in the dale [Fig. 1 (g)].

20        This substrate member is further polished with a polishing medium for CMP which can polish away both the barrier layer 14 and the wiring layer 15, so that as shown in Fig. 1 (h) a semiconductor substrate member is obtained in which the silicon dioxide 11 stands

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uncovered to the surface.

The first polishing medium for CMP of the present invention is the polishing medium comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water, and  
5 has been so regulated that it has a pH of 3 or less and contains the oxidizing agent in a concentration of from 0.01 to 3% by weight. It may further optionally contain water-soluble polymer and abrasive grains.

10 If the polishing medium for CMP has a high pH of more than 3, a low polishing rate may result on the tantalum, tantalum alloy and/or tantalum compound. The pH may be adjusted by controlling the amount of the acid to be added. It may also be adjusted by adding an alkali  
15 component such as ammonia, sodium hydroxide or tetramethylammonium hydride.

The polishing rate of the tantalum, tantalum alloy and/or tantalum compound reaches a maximum when the oxidizing agent for conductors is in a concentration  
20 of about 0.15% by weight. The oxidizing agent enables formation of a mechanically readily polishable primary oxide layer on the surface of the conductor film of the tantalum, tantalum alloy or tantalum compound, ensuring a high polishing rate.

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In general, when the polishing medium has a pH of less than 3, the etching rate of the copper or copper alloy film is so high as to make it difficult for the protective-film-forming agent to control the etching.

5 However, in the present invention, the oxidizing agent is in so sufficiently a low concentration that the protective-film-forming agent can make etching control.

If the oxidizing agent is in a high concentration of more than 3% by weight, not only the etching rate of  
10 the copper or copper alloy may be so high as to tend to cause the dishing, but also a secondary oxide layer which can be polished with greater difficulty than the primary oxide layer may be formed on the surface of the conductor film of the tantalum, tantalum alloy or tantalum  
15 nitride or other tantalum compound, resulting in a low polishing rate. If the oxidizing agent is in a concentration of less than 0.01% by weight, the oxide layer can not sufficiently be formed, resulting in a low polishing rate to even cause peeling of the tantalum  
20 film in some cases.

The polishing medium for CMP of the present invention may further contain abrasive grains. To achieve a high dispersion stability and make any polishing scratches less occur, the abrasive grains may preferably have an

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average particle diameter of 100 nm or less, and particularly preferably 50 nm or less.

A second polishing medium for CMP of the present invention is the polishing medium comprising an oxidizing agent for conductors, a protective-film-forming agent for protecting a metal surface, an acid, and water; the polishing medium further containing abrasive grains, and the abrasive grains having an average particle diameter of 50 nm or less and a standard deviation of particle size distribution, of more than 5 nm. This second polishing medium, too, may preferably be so regulated that it has a pH of 3 or less and contains the oxidizing agent for conductors in a concentration of from 0.01 to 3% by weight. If necessary, a water-soluble polymer may be added. Abrasive grains having an average particle diameter of 30 nm or less and having a standard deviation of particle size distribution of more than 10 nm are particularly preferred in the present invention. If they have a large average particle diameter of more than 50 nm, a low polishing rate may result on the barrier layer, and a high polishing rate on the silicon dioxide film. Also, even when they have an average particle diameter of 50 nm or less, a high polishing rate tends to result on the silicon dioxide film if their standard deviation

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of particle size distribution is less than 5 nm.

The oxidizing agent in the first or second polishing medium for CMP of the present invention may preferably be used in a concentration of from 0.01 to 1.5% by weight when the water-soluble polymer is contained. The water-soluble polymer comes adsorbed to the surface of the tantalum, tantalum alloy or tantalum compound or its oxide layer, and hence the oxidizing agent which contributes to the high polishing rate can be in a low concentration range. Also, the water-soluble polymer tends to come adsorbed especially to the surface of the nitride compound film such as tantalum nitride film or titanium nitride film, and hence it is considered that the polishing rate of the nitride compound film such as tantalum nitride film or titanium nitride film can be low. Meanwhile, the water-soluble polymer has the effect of forming a metal surface protective film to improve flat-surface retentivity against the dishing and thinning.

The oxidizing agent for conductors in the present invention may include hydrogen peroxide ( $H_2O_2$ ), nitric acid, potassium periodate, hypochlorous acid and ozone water. Of these, hydrogen peroxide is particularly preferred. Where the substrate member is a silicon



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substrate member including devices for integrated circuits, it is undesirable for it to be contaminated with alkali metals, alkaline earth metals, halides and so forth. Hence, an oxidizing agent not containing any  
5 in-volatile component is preferred. Here, since the ozone water may undergo a great compositional change with time, the hydrogen peroxide is most suited. However, where the substrate member to be polished is a glass substrate member not including any semiconductor devices,  
10 an oxidizing agent containing a in-volatile component may be used without any problem.

The acid used in the present invention may preferably be formic acid or an organic acid (such as acetic acid, propionic acid, valeric acid, 2-methylbutyric acid,  
15 n-hexanoic acid, 3,3-dimethylbutyric acid, 2-ethylbutyric acid, 4-methylpentanoic acid, n-heptanoic acid, 2-methylhexanoic acid, n-octanoic acid, 2-ethylhexanoic acid, benzoic acid, glycolic acid, salicylic acid, glyceric acid, oxalic acid, malonic acid,  
20 succinic acid, glutaric acid, adipic acid, pimelic acid, maleic acid, phthalic acid, malic acid, tartaric acid or citric acid). Also usable are salts such as ammonium salts of these, sulfuric acid, nitric acid, ammonia, ammonium salts as exemplified by ammonium persulfate,

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ammonium nitrate and ammonium chloride, and chromic acid, or mixtures of these. Of these, in view of an advantage that practical CMP polishing rate can be achieved, malonic acid, malic acid, tartaric acid, glycolic acid and citric acid are preferred.

The protective-film-forming agent in the present invention is selected from benzotriazole (BTA) and BTA derivatives (e.g., tolyltriazole, which is a compound in which one hydrogen atom of the benzene ring has been substituted with a methyl group; benzotriazole 4-carboxylic acid, which is a compound in which the same has been substituted with a carboxyl group; and methyl, ethyl, propyl, butyl and octyl esters thereof), naphthotriazole, and naphthotriazole derivatives, or mixtures containing any of these.

The water-soluble polymer used in the present invention may include polymers having as a basic building block a monomer having a carboxyl group, or salts thereof, as exemplified by polyacrylic acid, ammonium polyacrylate, sodium polyacrylate, polymethacrylic acid, ammonium polymethacrylate, sodium polymethacrylate and polyacrylamide; and polymers having as a basic building block a monomer having a vinyl group, as exemplified by polyvinyl alcohol and polyvinylpyrrolidone. Where,

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however, the substrate member to be polished is a silicon substrate member for semiconductor integrated circuits, it is undesirable for it to be contaminated with alkali metals, alkaline earth metals, halides and so forth.

5 Hence, acids or ammonium salts thereof are preferred.

Where the substrate member is a glass substrate member, the same does not necessarily apply. The addition of any of these water-soluble polymers enables improvement of dishing-preventive performance on account of the  
10 etching control effect attributable to the protective-film-forming agent.

The present invention also provides a polishing medium for CMP, having a polishing-rate ratio (Ta/Cu or TaN/Cu) between tantalum or tantalum nitride and copper  
15 (inclusive of copper alloys) of more than 1, and a polishing-rate ratio between tantalum or tantalum nitride and silicon dioxide (Ta/SiO<sub>2</sub> or TaN/SiO<sub>2</sub>) of more than 10.

As described above, where in the present invention  
20 the polishing medium for CMP has a low pH of less than 3 and a low oxidizing-agent concentration (the oxidizing agent is in a concentration of about 0.15% by weight), the polishing rate of the tantalum, tantalum alloy or tantalum nitride or other tantalum compound used as the

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barrier layer can reach a maximum. Where its pH is less than 3, the etching rate of the copper or copper alloy comes higher, but, because of the sufficiently low concentration of the oxidizing agent, can be controlled by the protective-film-forming agent. Also, where the abrasive grains of colloidal silica or colloidal alumina having an average particle diameter of 50 nm is used, which lowers the polishing rate of silicon dioxide, the polishing-rate ratio (Ta/Cu or TaN/Cu) between tantalum or tantalumnitride and copper (inclusive of copper alloys) can be made more than 1 and also the polishing-rate ratio (Ta/SiO<sub>2</sub> or TaN/SiO<sub>2</sub>) between tantalum or tantalumnitride and silicon dioxide can be made more than 10.

The abrasive grains usable in the polishing medium for CMP may be any of inorganic abrasive grains such as silica, alumina, ceria, titania, zirconia, germania and silicon carbide, and organic abrasive grains such as polystyrene, polyacrylic or polyvinyl chloride particles. Colloidal silica or colloidal alumina having an average particle diameter of 50 nm or less are preferred, as having a good dispersibility in the polishing medium and being less causative of polish marks (scratches) which may be caused by CMP. As their average particle diameter, those having an average particle diameter of 30 nm or

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less are preferred by which the polishing rate of the barrier layer can be made higher and the polishing rate of silicon dioxide film can be made lower, and those of 20 nm or less are particularly preferred. As the colloidal silica, a product obtained by hydrolysis of a silicon alkoxide or by ion exchange of sodium silicate may be used, for example. As the colloidal alumina, a product obtained by hydrolysis of aluminum nitrate may be used, for example.

10       The abrasive grains in the first or second polishing medium for CMP may preferably be added in an amount ranging from 0.01% by weight to 10% by weight, and more preferably from 0.05% by weight to 5% by weight, based on the total weight. If it is added in an amount of less than 0.01%  
15 by weight, there may be no significant difference from the polishing rate of a case not containing any abrasive grains. If it is more than 10% by weight, its addition in a larger quantity than that may no longer bring about any improvement of the rate of polishing by CMP.

20       The polishing medium for CMP of the present invention is especially suited for the polishing of conductors (inclusive of semiconductors) such as copper, copper alloys and copper oxides, and barrier layers for these (e.g., tantalum, tantalum alloys and tantalum compounds

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such as tantalum nitride.

The acid in the polishing medium of the present invention may be mixed in an amount of from 0.0001 to 0.05 mol, and more preferably from 0.001 to 0.01 mol, based on the total weight 100 g of the oxidizing agent for conductors, acid, protective-film-forming agent, water-soluble polymer and water. If it is mixed in an amount of more than 0.05 mol, the etching of the copper or copper alloy tends to proceed too much.

10 The protective-film-forming agent in the polishing medium of the present invention may be mixed in an amount of from 0.0001 to 0.01 mol, and more preferably from 0.0005 to 0.005 mol, based on the total weight 100 g of the oxidizing agent for conductors, acid, protective-film-forming agent, water-soluble polymer and water. If it is mixed in an amount of less than 0.0001 mol, the etching of the copper or copper alloy tends to proceed too much. If it is in an amount of more than 0.01 mol, there can be no change in the effect.

20 In the present invention, the water-soluble polymer may also be added, and the water-soluble polymer may be mixed in an amount of from 0.001 to 0.5% by weight, and more preferably from 0.01 to 0.2% by weight, based on the total weight 100 g of the oxidizing agent for

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conductors, acid, protective-film-forming agent, water-soluble polymer and water. If it is mixed in an amount of less than 0.001% by weight, the effect attributable to its use in combination with the

5 protective-film-forming agent tends not to be brought out in etching control. If it is in an amount of more than 0.5% by weight, a low rate of polishing by CMP tends to result.

The method of polishing the substrate by the use

10 of the polishing medium for CMP of the present invention is a polishing method in which the polishing medium for CMP is fed to a polishing pad on a polishing platen, and, bringing it into contact with a surface to be polished, the surface to be polished and the polishing pad are

15 relatively moved to polish the surface. As an apparatus for such polishing, a commonly available polishing apparatus may be used which has a holder for holding a semiconductor substrate member having the surface to be polished and a polishing platen to which the polishing

20 pad has been fastened (fitted with, e.g., a motor whose number of revolutions is variable). As the polishing pad, commonly available nonwoven fabric, foamed polyurethane, porous fluorine resin and so forth may be used without any particular limitations. There are

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no particular limitations on polishing conditions. It is preferable to rotate the polishing platen at a low rotation of 200 rpm or less so that the substrate does not rush out therefrom. The semiconductor substrate member having the surface to be polished (the film to be polished) may preferably be pressed against the polishing pad at a pressure of from 9.8 to 98.1 kPa (from 100 to 1,000 gf/cm<sup>2</sup>), and more preferably from 9.8 to 49.0 kPa (from 100 to 500 gf/cm<sup>2</sup>) in order to satisfy the wafer in-plane uniformity of polishing rate and the flatness of patterns. In the course of the polishing, the polishing medium for CMP is continuously fed to the polishing pad. There are no particular limitations on this feed quantity. It is preferable for the polishing-pad surface to be always covered with the polishing medium. The semiconductor substrate member on which the polishing has been completed may preferably be washed thoroughly in running water and thereafter be set on a spin dryer to blow off any drops of water adhering onto the semiconductor substrate member, followed by drying.

#### EXAMPLES

The present invention is specifically described below by giving Examples. The present invention is by no means



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limited by these Examples.

(1) Preparation of polishing medium for chemical-mechanical polishing:

As shown in Table 1, to a mixture of 0.4% by weight  
5 of an acid, abrasive grains (but not added in Example  
1; 1 part by weight in Examples 2 to 9; and 1% by weight  
in Examples 10 to 13), 0.05 part by weight of a water-soluble  
polymer (but only in Examples 4, 6 and 7) and 0.2% by  
weight of a protective-film-forming agent (BTA), water  
10 (98.85 parts by weight in Examples 1 to 9, and 97.9%  
by weight in Examples 10 to 13) was added to effect  
dissolution, followed by addition of hydrogen peroxide  
water (a guaranteed reagent, an aqueous 30% solution)  
as an oxidizing agent for conductors to obtain polishing  
15 mediums for CMP. Here, as the abrasive grains, colloidal  
silica with an average particle diameter of 20 to 60  
nm was added which was prepared by hydrolysis in an ammonia  
solution of tetraethoxysilane. Also, the malic acid and  
glycolic acid used each had a pKa of 3.2.

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Table 1

Example	Acid	hydrogenperoxide concentration (wt.%)	pH	Abrasive grains (colloidal silica)		Water-soluble polymer
				Av. Particle diameter (nm)	Standard deviation of particle size distribution (nm)	
1	glycolic acid	0.15	2.58	—	—	none
2	malic acid	0.15	2.50	20	10	none
3	malic acid	1.5	2.49	20	10	none
4	malic acid	0.15	2.80	20	10	ammonium polyacrylate
5	glycolic acid	0.15	2.58	20	10	none
6	glycolic acid	0.15	2.95	20	10	ammonium polyacrylate
7	malic acid	1.8	2.76	20	10	ammonium polyacrylate
8	malic acid	3.3	2.45	20	10	none
9	malic acid	0.15	3.25	20	10	none
10	malic acid	0.15	2.50	25	10	none
11	malic acid	0.15	2.50	40	14	none
12	malic acid	0.15	2.52	60	13	none
13	malic acid	0.15	2.51	30	5	none

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## (2) Polishing:

Using the polishing mediums for CMP thus obtained, CMP was carried out. Polishing conditions are as follows:  
Substrate member:

- 5        Silicon substrate with a tantalum film formed thereon  
in a thickness of 200 nm.

      Silicon substrate with a tantalum nitride film formed  
thereon in a thickness of 100 nm.

- Silicon substrate with a silicon dioxide film formed  
10    thereon in a thickness of 1  $\mu\text{m}$ .

      Silicon substrate with a copper film formed thereon  
in a thickness of 1  $\mu\text{m}$ .

Polishing pad:

- Foamed polyurethane resin with closed cells.  
15    Polishing pressure: 250 gf/cm<sup>2</sup>.

Relative speed of substrate member to polishing platen:  
18 m/minute.

## (3) Polished-product evaluation items:

- 20    On the polished products having been processed by  
CMP, evaluation was made on the following items.

Rate of polishing by CMP:

Determined by calculation from electrical resistance  
value in respect of the difference in layer thickness

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before and after the film was polished by CMP.

Etching rate:

Determined by calculation from electrical resistance value in respect of the difference in copper layer

- 5 thickness before and after immersion in the polishing medium for chemical-mechanical polishing, having been stirred at 25°C and 100 rpm.

Dishing level:

- A silicon substrate having thereon a silicon dioxide  
10 film in which grooves of 0.5  $\mu\text{m}$  in depth were formed, a tantalum nitride film formed thereon by known sputtering in a thickness of 50 nm as the barrier layer and a copper film similarly formed thereon by sputtering and buried in the groove by known heat treatment was used as a substrate  
15 member, and was subjected to two-step polishing. Then, from the surface profile of a pattern area in which stripes of 100  $\mu\text{m}$  in width for the part of wiring metal and 100  $\mu\text{m}$  in width for the part of insulating film were arranged alternately, the level of film loss at the part of wiring  
20 metal with respect to the part of insulating film was determined by means of a stylus surface profilometer.

As the first-stage polishing medium for copper, a polishing medium for copper and copper alloys, having a sufficiently large polishing-rate ratio of the copper

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to the tantalum nitride, was used to carry out the polishing.

After the first-stage polishing, a substrate member sample was so prepared that the dishing level measured in the state the barrier layer stood uncovered onto the part of insulating film came to 50 nm, and was then subjected to the second-stage polishing using the above polishing medium for chemical-mechanical polishing, until the barrier layer came lost at the part of insulating film. Thinning level:

10       The surface profile of a pattern area in which stripes of 2.5 mm in total width, consisting of 45  $\mu\text{m}$  in width for the part of wiring metal and 5  $\mu\text{m}$  in width for the part of insulating film which were arranged alternately, formed in the substrate member used to evaluate the above

15       dishing level, was measured with the stylus surface profilometer to determine the level of film loss at the part of insulating film in the vicinity of the middle of the pattern with respect to the part of the insulating film field around the stripe pattern. After the

20       first-stage polishing, a substrate member sample was so prepared that the thinning level measured in the state the barrier layer stood uncovered onto the part of insulating film came to 20 nm, and was then subjected to the second-stage polishing using the above polishing

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medium for chemical-mechanical polishing, until the barrier layer came lost at the part of insulating film.

(4) Evaluation results:

The rate of polishing by CMP in each Example is shown  
5 in Table 2. Also, the dishing level and the thinning level are shown in Table 3.

Table 2

Example	CMP polishing rate (nm/minute)				Copper etching rate (nm/minute)
	Copper	Tantalum	Tantalum nitride	silicon dioxide	
1		4.0	5.0	0	0.5
2		36.2	54.7	0.8	0.8
3		24.9	44.9	1.3	3.2
4		34.9	24.9	1.2	0.3
5		33.0	61.5	1.3	0.7
6		20.0	25.0	1.3	0.6
7		1.1	5.5	1.7	0.4
8		10.5	17.3	1.2	6.7
9		2.0	3.0	0.7	0.1
10	11.4	36.2	54.7	0.8	
11	3.2	28.8	43.2	0.8	
12	13.0	22.0	43.4	6.7	
13	23.4	30.4	57.7	9.5	

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Table 3

	Example												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Dishing level (nm)	40	55	70	45	55	45	65	100	55	40	40	60	55
Thinning level (nm)	20	30	35	30	35	30	70	55	70	20	20	60	100

In Examples 1 to 13, good dishing- and thinning-preventive performance has been achieved. In particular, in Examples 1 to 6, in which the oxidizing agent is in a concentration of from 0.01 to 3% by weight and the pH is 3 or less, the polishing rates of tantalum and tantalum nitride are so high and the dishing level and thinning level are so small as to be especially preferable. Also, in Examples 10 and 11, the polishing rate of tantalum nitride film is high and the polishing rate of silicon dioxide film is relatively low, and hence good dishing- and thinning-preventive performance is achieved.

In particular, in Examples 4 and 6, in which the water-soluble polymer is used and the oxidizing agent is in a concentration ranging from 0.01 to 1.5% by weight, the dishing and the thinning occur in a smaller level, showing better results, than Example 7, in which the oxidizing agent is added in a larger quantity (1.8% by

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weight). Here, when the water-soluble polymer is used, it is preferable for the water-soluble polymer to be added in a concentration of from 0.01 to 1.5% by weight.

If it is added in an amount larger than that, a low  
5 polishing rate tends to result on the tantalum or tantalum nitride and the thinning may occur in a large level.

Example 2, in which the oxidizing agent is in a concentration of 3% by weight or less and the pH is 3 or less, is also preferable because the etching rate  
10 of copper is lower than that in Example 8, in which the oxidizing agent is in a concentration of more than 3% by weight, and also the polishing rate of tantalum or tantalum nitride is higher and the level of dishing and thinning is smaller than those in Example 9, in which  
15 the pH is more than 3.

In Examples 10 and 11, the polishing rate of the barrier layer film (in particular, the tantalum film) is higher and the polishing rate of the silicon dioxide film is lower than those in Example 12, in which the  
20 abrasive grains have a large particle diameter. Thus, these Examples are superior in view of the dishing- and thinning-preventive performance. Also, in Examples 10 and 11, the polishing rate of the barrier layer film (in particular, the tantalum film) is at the same rank



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as, but the polishing rate of the silicon dioxide film is lower than, those in Example 13, in which the standard deviation of particle size distribution is smaller.

5                    POSSIBILITY OF INDUSTRIAL APPLICATION

As described above, according to the present invention, the tantalum, tantalum alloy or tantalum compound or the like used as the barrier layer can efficiently be polished, and also the dishing, thinning  
10 and polish scratches can be kept from occurring in copper or copper alloy wirings to form highly reliable buried metal film patterns.

## WHAT IS CLAIMED IS

1           1. A polishing medium for chemical-mechanical  
2 polishing, comprising:

3           an oxidizing agent for a conductor; a  
4 protective-film-forming agent for protecting a metal  
5 surface; an acid; and water, wherein

6           said polishing medium has a pH of 3 or less, and  
7           said oxidizing agent is in a concentration of from  
8 0.01% by weight to 3% by weight.

1           2. The polishing medium for chemical-mechanical  
2 polishing according to claim 1, which further comprises  
3 abrasive grains.

1           3. The polishing medium for chemical-mechanical  
2 polishing according to claim 2, wherein:  
3           said abrasive grains have a average particle diameter  
4 of 50 nm or less, and  
5           said abrasive grains have standard deviation of  
6 particle size distribution in a value of more than 5  
7 nm.

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1           4. A polishing medium for chemical-mechanical  
2 polishing, comprising:  
3           abrasive grains, an oxidizing agent for a conductor:  
4 a protective-film-forming agent for protecting a metal  
5 surface; an acid; and water, wherein:  
6           said abrasive grains have an average particle  
7 diameter of 50 nm or less, and  
8           said abrasive grains have standard deviation of  
9 particle size distribution in a value of more than 5  
10 nm.

1           5. The polishing medium for chemical-mechanical  
2 polishing according to claim 4, wherein:  
3           said polishing medium for chemical-mechanical  
4 polishing has a pH of 3 or less, and  
5           said oxidizing agent for a conductor is in a  
6 concentration of from 0.01% by weight to 3% by weight.

1           6. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 2 to 5, wherein:  
3           said abrasive grains are at least one selected from  
4 silica, alumina, ceria, titania, zirconia and germania.

1           7. The polishing medium for chemical-mechanical

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2 polishing according to claim 6, wherein said abrasive  
3 grains are colloidal silica or colloidal alumina.

1 8. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 2 to 7, wherein  
3 said abrasive grains are mixed in an amount of from 0.1%  
4 by weight to 5% by weight.

1 9. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 8, which  
3 further comprises a water-soluble polymer.

1 10. The polishing medium for chemical-mechanical  
2 polishing according to claim 9, wherein said water-soluble  
3 polymer is at least one selected from the group consisting  
4 of polyacrylic acid, a polyacrylic acid salt,  
5 polymethacrylic acid, a polymethacrylic acid salt,  
6 polyamic acid, a polyamic acid salt, polyacrylamide,  
7 polyvinyl alcohol and polyvinylpyrrolidone.

1 11. The polishing medium for chemical-mechanical  
2 polishing according to claim 9 or 10, wherein said  
3 oxidizing agent is in a concentration of from 0.01% by  
4 weight to 1.5% by weight.

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1           12. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 11, wherein  
3 said acid is an organic acid.

1           13. The polishing medium for chemical-mechanical  
2 polishing according to claim 12, wherein said acid is  
3 at least one selected from malonic acid, malic acid,  
4 tartaric acid, glycolic acid and citric acid.

1           14. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 13, wherein  
3 said protective-film-forming agent is at least one  
4 selected from benzotriazole and a derivative thereof.

1           15. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 14, wherein  
3 said oxidizing agent for a conductor is at least one  
4 selected from hydrogen peroxide, nitric acid, potassium  
5 periodate, hypochlorous acid and ozone water.

1           16. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 15, wherein  
3 said conductor contains at lest one of copper, a copper  
4 alloy, a copper oxide and a copper alloy oxide.

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1           17. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 15, wherein  
3 said conductor is a barrier layer for preventing copper  
4 atoms from diffusing.

1           18. The polishing medium for chemical-mechanical  
2 polishing according to claim 17, wherein said barrier  
3 layer contains tantalum, a tantalum alloy or a tantalum  
4 compound.

1           19. A polishing medium for chemical-mechanical  
2 polishing having:  
3           a polishing-rate ratio (Ta/Cu) between tantalum and  
4 copper or a copper alloy of more than 1;  
5           a polishing-rate ratio (Ta<sub>N</sub>/Cu) between tantalum  
6 nitride and copper or a copper alloy of more than 1;  
7           a polishing-rate ratio (Ta/SiO<sub>2</sub>) between tantalum  
8 and silicon dioxide of more than 10; and  
9           a polishing-rate ratio (Ta<sub>N</sub>/SiO<sub>2</sub>) between tantalum  
10 nitride and silicon dioxide film of more than 10.

1           20. The polishing medium for chemical-mechanical  
2 polishing according to any one of claims 1 to 18, which  
3 has:

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4 a polishing-rate ratio (Ta/Cu) between tantalum and  
5 copper or a copper alloy of more than 1;  
6 a polishing-rate ratio (TaN/Cu) between tantalum  
7 nitride and copper or a copper alloy of more than 1;  
8 a polishing-rate ratio (Ta/SiO<sub>2</sub>) between tantalum  
9 and silicon dioxide of more than 10; and  
10 a polishing-rate ratio (TaN/SiO<sub>2</sub>) between tantalum  
11 nitride and silicon dioxide film of more than 10.

1 21. A method of polishing a substrate member  
2 comprising a step of polishing a barrier layer containing  
3 tantalum, a tantalum alloy or a tantalum compound, by  
4 the use of the polishing medium for chemical-mechanical  
5 polishing according to any one of claims 1 to 19.

1 22. A method of polishing a substrate member  
2 comprising a step of polishing a surface including a  
3 wiring layer and a barrier layer, by the use of the polishing  
4 medium for chemical-mechanical polishing according to  
5 any one of claims 1 to 19.

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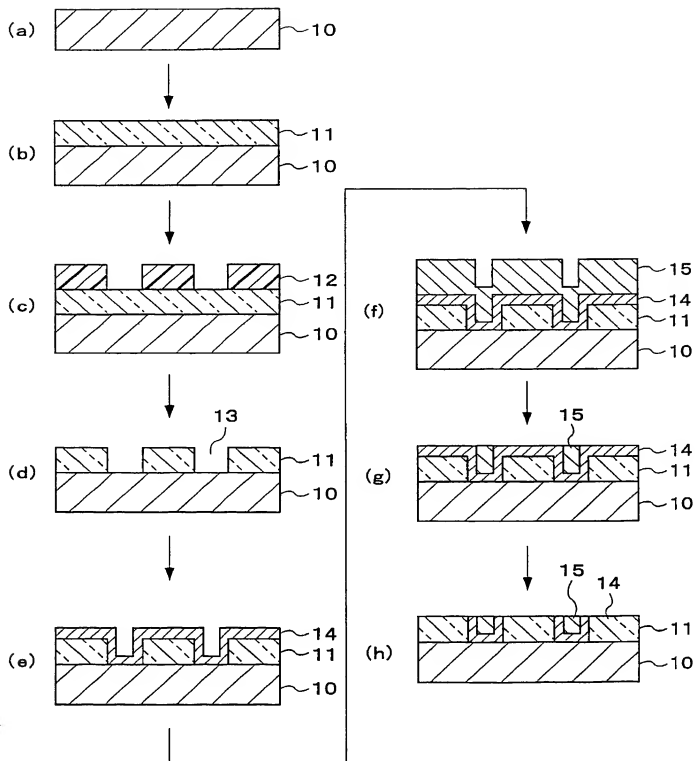
## ABSTRACT

This invention provides a polishing medium for chemical-mechanical polishing, comprising an oxidizing agent for a conductor, a protective-film-forming agent for protecting a metal surface, an acid, and water; (1) the polishing medium having a pH of 3 or less, and the oxidizing agent being in a concentration of from 0.01 to 3% by weight, or (2) the polishing medium containing abrasive grains having an average particle diameter of 50 nm or less, and the abrasive grains having standard deviation of particle size distribution in a value of more than 5 nm.



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FIG. 1



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# Declaration and Power of Attorney for Patent Application

特許出願宣言書及び委任状

## Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

金属用研磨液及び基板の研磨法

POLISHING MEDIUM FOR CHEMICAL-MECHANICAL

POLISHING, AND METHOD OF POLISHING SUBSTRATE

MEMBER

上記発明の明細書（下記の欄で印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

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(該当する場合) 2002年2月15日に訂正されました。

☒ was filed on August 17, 2000 /  
as United States Application Number or PCT  
International Application Number  
PCT/JP00/05508 and was amended on  
February 15, 2002 (if applicable)

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

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I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

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外国での先行出願

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(番号)

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Hei11-308665 ✓  
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(Filing Date)  
(出願日)

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(Application No.)  
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(出願番号)

(Filing Date)  
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私は、私自身の知識に基づいて本宣言書中で私が行う表明が真実であり、かつ私の入手した情報と私の信ずるところに基づく表明がすべて真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような虚偽による虚偽の声明を行えば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

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August 17, 1999 ✓  
(Day/Month/Year Filed)  
(出願年月日)

☐

October 29, 1999 ✓  
(Day/Month/Year Filed)  
(出願年月日)

☐

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(出願番号)

(Filing Date)  
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I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Status)(patented, pending, abandoned)  
(現況：特許許可済、係属中、放棄済)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Docket No. 566.41191X00

委任状： 私は、下記の発明者として、本出願に関する一切の手続を米国特許商標局に対して遂行する弁理士又は代理人として、下記のものを指名致します。(弁護士、又は代理人の氏名及び登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: (*list name and registration number*)

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(第三以降の共同発明者についても同様に記載し、署名をすること。)

(Supply similar information and signature for third and subsequent joint inventors.)

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Docket No. 566.41191X00

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第四発明者の署名 日付	Fourth inventor's signature <u>Hiroki Terasaki</u> Date <u>April 15, 2002</u>
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国籍 日本	Citizenship <u>Japan</u> ✓
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第五発明者の署名 日付	Fifth inventor's signature <u>Akiko Igarashi</u> Date <u>April 15, 2002</u>
住所	Residence <u>Ibaraki, Japan JPX</u>
国籍 日本	Citizenship <u>Japan</u> ✓
郵便の宛先	Post office address c/o Research & Development Center, HITACHI CHEMICAL CO., LTD. 48, Wadai, Tsukuba-shi, Ibaraki 300-4247 Japan

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